Naturally occurring coastal hypoxia:
A decade of oxygen in the Monterey Bay

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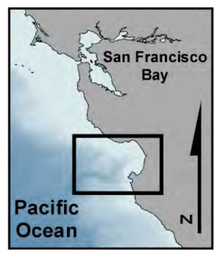
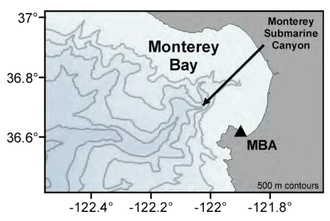
Natural Hypoxia



Oxygen in marine ecosystems is crucial to life, but the world's oceans are becoming more hypoxic through cascading effects of climate change and anthropogenic eutrophication. It is important to understand situations where natural hypoxia occurs in order to further explain ecosystem variability, biological tolerances and to prevent additive effects with anthropogenic hypoxia.

In July of 1999, the Monterey Bay Aquarium experienced a hypoxia induced fish die-off in a tank fed with raw seawater from their intake pipe drawn from the adjacent kelp bed. An oxygen sensor was installed in their sea water intake system to warn of future hypoxic exposure. This decade long dataset was used to understand hypoxia in coastal Monterey Bay.



Oxygen in the Ocean

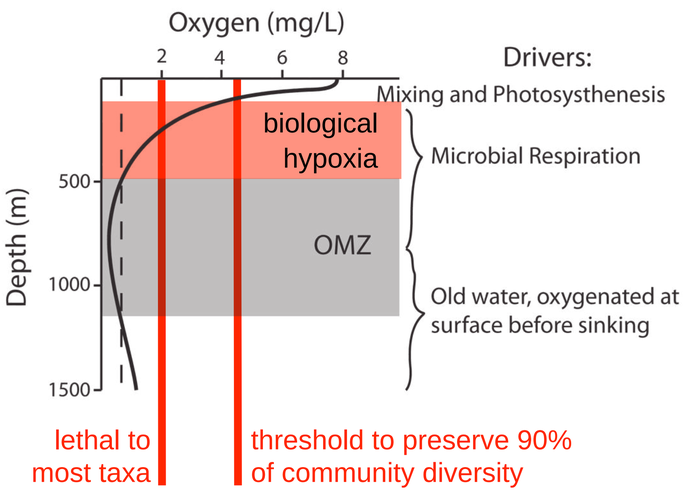
Oxygen Minimum Zones

Oceanic hypoxic regions occur naturally between depths of 200-1200 m in areas of high primary productivity, including the California Current, caused by aerobic decomposition of organic matter as it sinks through a deep, stable water column. Water associated with these oxygen minimum zones (OMZ <~0.5 mg/L) is cold, hypoxic and acidic.

Nutrients → Photosynthesis → Microbial Respiration

Biological Hypoxic Thresholds

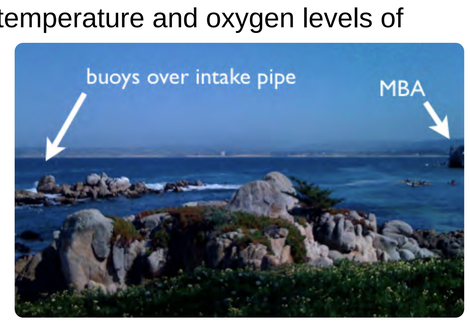
Biological hypoxia is typically described as below 2 mg/L, which is lethal to most taxa. However, Vaquer-Sunyer and Duarte (2008) determined that to preserve 90% of community diversity, oxygen levels should remain above 4.6 mg/L to avoid the majority of detrimental effects on the more sensitive species.



Methods

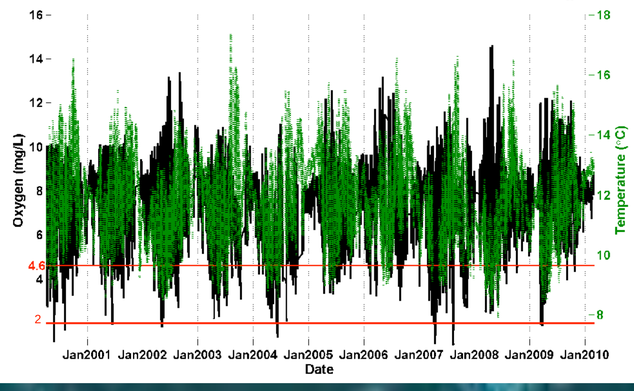
Monterey Bay Aquarium seawater intake

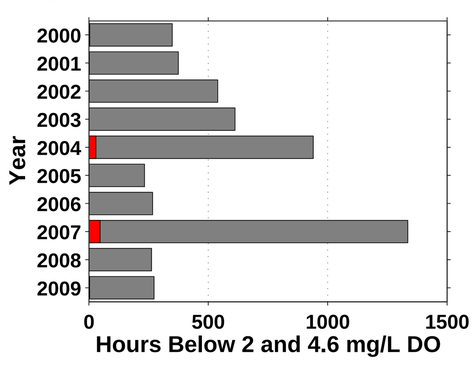
Over the last 10 years the Monterey Bay Aquarium has been monitoring temperature and oxygen levels of seawater drawn from intakes at 17m depth every 5 min. Oxygen measurements were confirmed with a CTD-oxygen profiler.

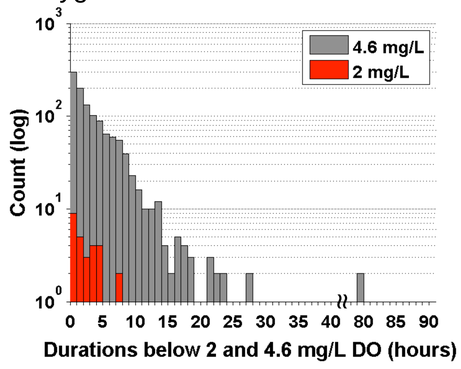


A Decade of Oxygen and Temperature

No inter-annual trends were found but a strong seasonal signal was seen in both temperature and oxygen.

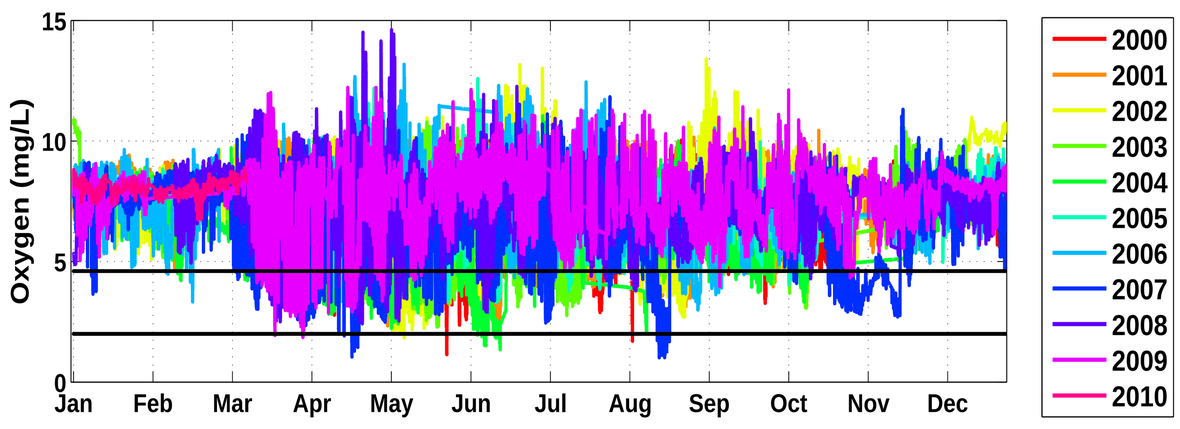


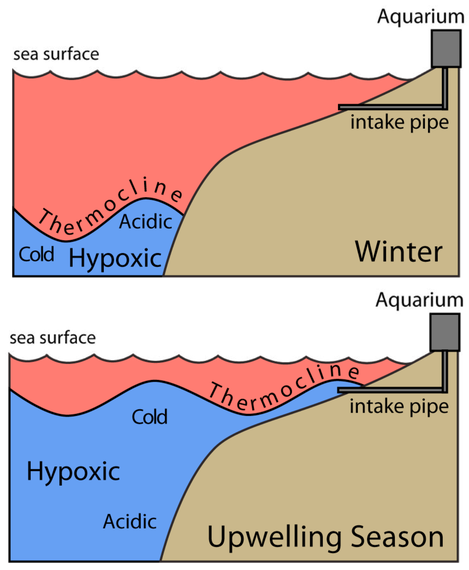




Seasonal Oxygen Variation and Upwelling

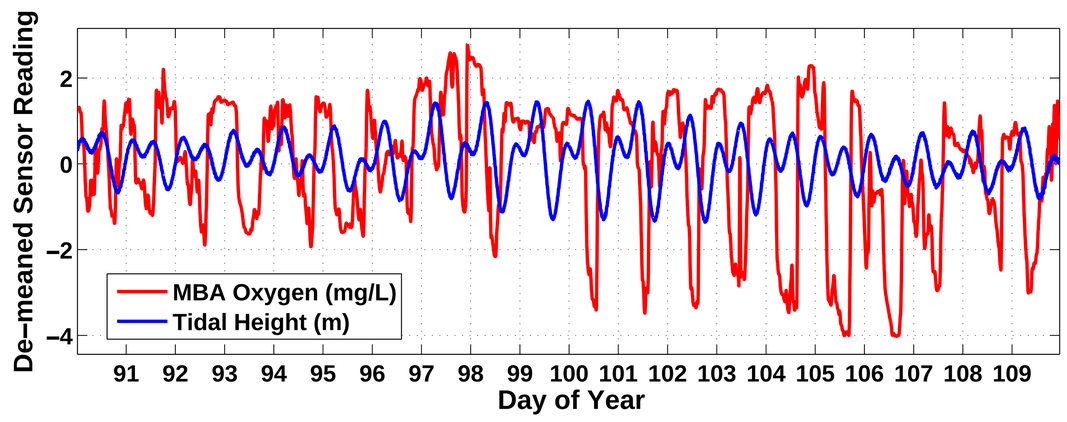
In winter (Nov-Feb) oxygen concentration tends to be quite stable, but in spring and summer (Mar-Oct), variability is extreme. The onset of fluctuations in March roughly coincides with beginning of the upwelling season.

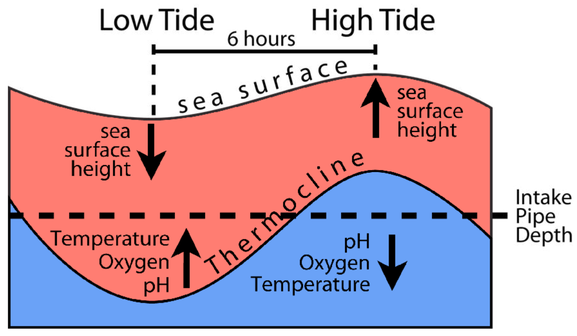




Diurnal Oxygen Variation and Internal Tides

Temperature and oxygen are clearly correlated, and the most severe short-term variations occur diurnally and are positively correlated with tidal height at a lag of 6 hours. This correlation to the tides is consistent with a rising and falling of the thermocline driven by internal tidal waves.





Conclusions

We propose that these nearshore hypoxic episodes are associated with the shoaling of the thermocline during the upwelling season and then sub-surface, internal tides move hypoxic waters vertically onto the shelf and inshore.

Future Research

Recent studies have reported a shoaling of the OMZ globally (Stramma et al., 2010) and within the California Current (Bograd et al., 2008), suggesting that the frequency, intensity, duration and spatial extent of this type of hypoxic intrusion may increase in the future. Although nearshore ecosystems may be adapted to these natural events, there may be a relatively small safety factor. It is important to assess hypoxia tolerance of at-risk communities, monitor changes in the OMZ, and develop predictive models that warn of incipient events.

References

Bograd, S.J., Castro, C.G., Di Lorenzo, E., Palacios, D.M., Bailey, H., Gilly, W., Chavez, F.P., 2008. Oxygen declines and the shoaling of the hypoxic boundary in the California Current. Geophys. Res. Lett. 35, L12607, doi:10.1029/ 2008GL034185.

Stramma, L., Schmidtko, S., Levin, L.A., Johnson, G.C., 2010. Ocean oxygen minima expansions and their biological impacts, Deep-Sea Res. (1 Oceanogr. Res. Pap.), 57:4, 587-595.

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